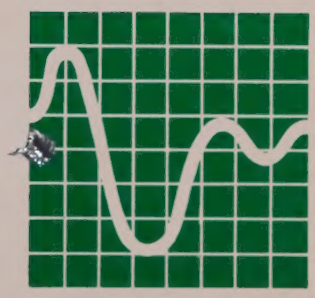
INSTRUCTION MANUAL

FOR

QRE MODELS

7.5-10 and 7.5-20

POWER SUPPLIES



SORENSEN POWER SUPPLIES

Manual No. 14-6324
JUNE 1967

INSTRUCTION MANUAL
FOR
QRE MODELS
7.5-10 and 7.5-20
POWER SUPPLIES

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RAYTHEON COMPANY, Sorensen Operation

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SECTION I
INTRODUCTION AND DESCRIPTION

1-1. INTRODUCTION.

1-2. This manual provides operation and maintenance instructions for the QRE 7.5-10 & 7.5-20 power supplies, manufactured by Raytheon Co., Sorensen Operation.

1-3. The manual is subdivided into six sections. Section I contains a description of the units, as well as a tabular listing of complete unit specifications. Details on initial inspections and checkout procedures are given in Section II. Operating instructions, including methods for adapting units for various applications, comprise Section III. Sections IV and V provide the principles of operation and maintenance procedures, respectively. A replacement parts list forms Section VI.

1-4. DESCRIPTION.

1-5. The QRE 7.5-10 & 7.5-20 power supplies accept a nominal 115, 220 or 230 Vac input and provide a highly regulated, precise d-c output. The units react extremely fast to load and line excursions and exhibit very low output ripple.

1-6. The use of silicon semiconductors gives the units their wide ambient temperature ranges and, as a maintenance feature, reduces the number of components. These components are protectively packaged in a compact, sturdy, cold-rolled steel case, which is finished in a baked-on, gun-metal grey enamel. High-dissipation components are mounted on an extrusion-type heatsink and,in the case of the QRE 7.5-20 units, are forced-air cooled.

1-7. An anodized-aluminum front panel mounts all of the operating controls used under normal conditions. These include the input POWER breaker, an OVERVOLT TRIP ADJ., a CUR.LIMIT ADJ., and a fine and coarse VOLT.ADJ. In addition, front-panel indicators include THERMAL OVERLOAD (QRE 7.5-20 only) and POWER ON lamps as well as an output ammeter and voltmeter. A knob-operated fuseholder on tne rear panel (the front panel for QRE 7.5-10 units) contains the input fuse. The rear-panel also supports a mode-adaptation terminal board. Output terminals are located both at the terminal board and on the front panel. Safety features include a grounded chassis (when the power cord plug is properly used).

1-8. Failure protection is offered not only by the input fuse but by two electronic control circuits. One monitors the output voltage and, if an overvoltage condition occurs, acts to open the input circuit breaker; the other senses the load current, and in the event of a high current condition, e.g., short circuit, limits the output current to a predetermined value. Although designed primarily for over current protection, the limit circuit is also a current regulator, offering a regulation of $\pm$ 0.1% I_O rated.

1-9. In addition to its many fine electrical and mechanical characteristics, the unit features a variety of operating configurations to service a number of applications. These include remote sensing, series and parallel operation and remote programming.

1-10. REMOTE SENSING. Terminals located on the rear-mounted terminal board offer the means of extending the unit's regulating point from the output terminals to the load. This, in effect, compensates for the IR drop in the load lines. The QRE will compensate for a maximum drop of 1.5 volts per load lead.

1-11. SERIES OPERATION. For applications requiring output voltages higher than any single QRE can supply, a number of QRE units may be

	QRE MODELS (6)	
	7.5-10	7.5-20
Input Ratings		
Voltage range (Vac)	105-125/200-240/210-250	
Frequency (Hz)	48 - 480	48 - 65
Phase	Single	
Max.Current (Aac) at 115 Vac	2.5	5.0
at 230 Vac	1.25	2.5
Power Factor (typical)(1)	0.81	0.85
Efficiency (typical)(%)(1)	37	33
Output Ratings		
Voltage range (Vdc)	0 - 7.5	
Resolution (typical) (mV)	1.4	
Current range at 40°C (Adc)(2)	0 - 10	0 - 20
Current limit range (Adc) (See Fig. 1-2.)	1 - 10.5	2 - 21
Regulation		
Voltage (for combined line & load)	± 0.01% or ± 0.4 mV(3)	
Current (for load or line)	± 0.1% of Io rated	
Ripple		
Max.RMS ripple voltage at 50-60 Hz	300 µV	
at 400 Hz (typ)	290 µV	
Max. peak-to-peak at 50-60 Hz	2 mV	
at 400 Hz (typ)	27 mV	
Transient Response (typical)(4)	50 µs	
Turn-Off and Turn-On Output Voltage Overshoots	None	
Ambient Temperature Range	0 - 71°C	
Remote Programming	100 ohms/volt ± 0.5	
Output Impedance (R + JωL)	75 µΩ + 0.32 µh	38 µΩ + 0.32
Temperature Coefficient (typical)	0.015%/°C or 0.5 mV/°C(3)	
Stability (8 hr after warm-up)	0.025%/8 hrs. (typical)	

(1.) At nominal input and full-rated output.
(2.) See Figure 1-1 for derating characteristics.
(3.) Whichever is greater.
(4.) For a step-load change from NL to FL, or FL to NL, and recovery to within ± 10 mV band.

Table 1-1. Unit Specifications (Sheet 1 of 2)

	QRE MODELS (6)	
	7.5-10	7.5-20
Series Operation	Up to 200 Vdc total output	
Parallel Operation (typical)	See Note 5	
Remote Sensing	Max. drop of 1.5 V/Leg	
Overvoltage Protection		
Adjustable range	3.5 - 10.5 V dc	
Reaction time (typical)	10 μs	
Cooling	Convection	Forced Air
RFI Characteristics (typical)	Meets Mil-I-26600, Mil-I-6181, Mil-I-16910	
Hi-pot Test		
Input Terminal - to - ground	1000 Vdc	
Output Terminal - to - ground	200 Vdc	
Dimensions (in.)		
Width	19	
Height	3-1/2	5-1/4
Depth	13-1/4	12-7/8
Weight (lb)	26	37

(5.) Derate each unit to 90% of maximum current. For a discussion concerning the number of units which may be paralleled, refer to para 3-21.
(6.) Unit output specifications are applicable at rear terminals only.

Table 1-1. Unit Specifications (Sheet 2 of 2)

connected in series to provide a maximum output of 200 volts. Regulation in series operation is the sum of the regulation of all units.

1-12. PARALLEL OPERATION. Parallel operation may be used to service those applications requiring a higher output current than any single QRE can provide. Paralleling is indirect through a "master-slave" approach. The maximum number of units which may be paralleled is discussed in para 3-21.

1-13. REMOTE PROGRAMMING. Some applications require that step changes be made in the unit output from remote locations. To service these, the unit has been made adaptable to remote programming. The adapting procedure entails only the connection of a calculated resistor or resistors into the programming circuit. Programming sensitivity is 100 ± 0.5 ohms/volt.

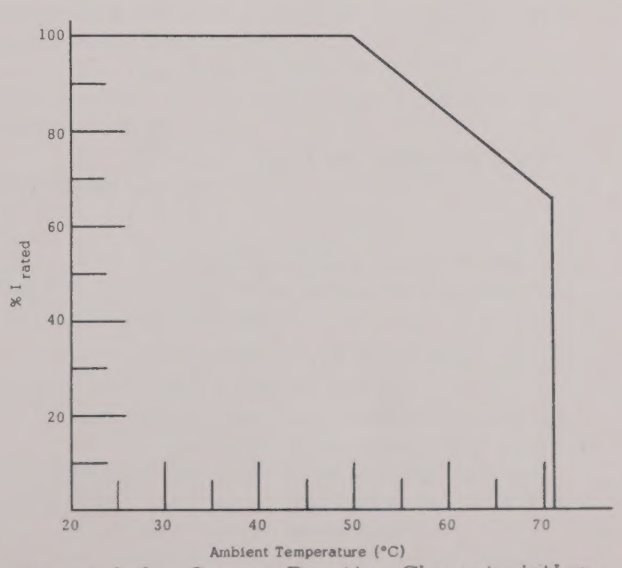


Figure 1-1. Current Derating Characteristics

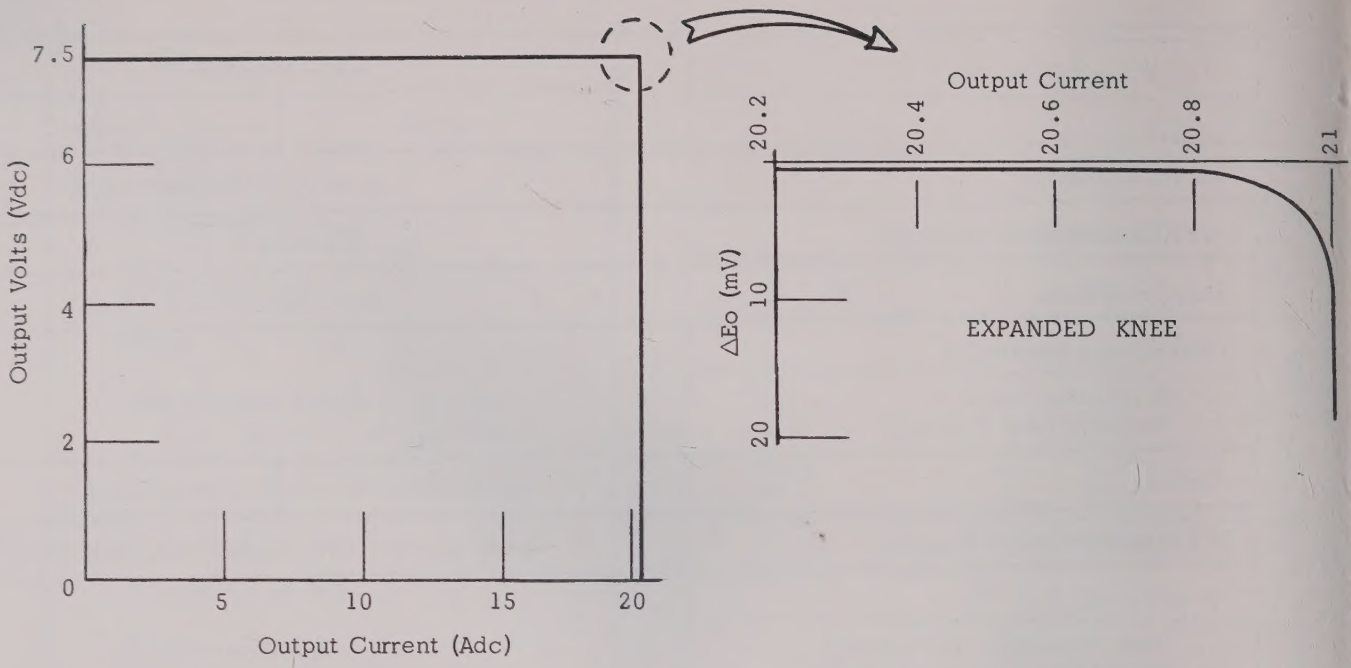


Figure 1-2. Typical Current Limit Characteristic (20-A Model)

SECTION II
PREPARATION FOR USE

2-1. GENERAL.

2-2. After unpacking, initial inspections and preliminary checkout procedures should be performed to assure that the unit is in good working order. Basically, these consist of visually checking for damaged parts and components, and of making an electrical check. If it is determined that the unit is damaged, follow the instructions on the Damage and/or Loss in Shipment form enclosed with the unit, and notify the carrier immediately. The carrier's claim agent will then prepare a report of damage. The user is required to send this report to the Service Department, Raytheon Company, Sorensen Operation, Richards Avenue, Norwalk, Connecticut. Sorensen will, in turn, advise the user as to what action is required to repair or replace the supply.

2-3. In addition to inspection and check-out procedures, this section contains instructions on altering unit input wiring for either 220- or 230-volt operation.

2-4. INITIAL INSPECTION.

2-5. Proceed as follows to inspect for damage incurred during shipment:

a. Inspect panel and chassis for dents, chips and other signs of structural damage.

b. Check action of fuseholder. Assure that holder contains a 5A fuse for the QRE 7.5-10 Units and a 10A fuse for the QRE 7.5-20 Units.

c. Turn all front-panel controls from stop-to-stop. Rotation should be smooth.

d. Set POWER circuit breaker to ON and then OFF. Action should be both positive and audible.

e. Check indicator lamps for cracked or broken lenses.

f. Inspect for cracked or broken meter windows. Check meter-pointer zero setting. Reset to zero using adjust screw, if necessary.

g. Check power input cord for obvious signs of damage. Tug lightly on cord near chassis to make certain relief grommet grips cord.

h. Inspect terminal board. Assure that links are firmly in place across terminals 1 and 2, 3 and 4, 5 and 6, and 7 and 8.

i. Remove screws retaining top cover to chassis. Inspect components for physical damage. If unit is to be rewired for an alternate input, proceed to para 2-6 before remounting cover.

2-6. ELECTRICAL INSTALLATION.

2-7. The unit is factory wired to accept a 115 Vac input. However, either of two alternate inputs may be used by making a few wiring alterations. The following two paragraphs describe the procedures.

2-8. 220-VOLT OPERATION. To alter the unit from 115 to 220-volt operation, see Figure 2-1 and proceed as follows:

a. At transformer T1, unsolder jumpers across taps 1 and 3, and 2 and 5.

b. Solder a jumper across taps 2 and 3.

c. Unsolder the white wire at tap 5, and resolder at tap 4.

d. At the internal terminal strip located on the front panel directly below the two lamp assemblies, cut the jumper across resistor R34 (QRE 7.5-20 units only).

e. Replace fuse F1 with a 2.5 A rated fuse for QRE 7.5-10 units. Use a 5 A fuse for the QRE 7.5-20 units.

f. Remount the cover using the hardware originally removed.

2-9. 230-VOLT OPERATION. To alter unit from 115 to 230-volt operation, see Figure 2-1 and proceed as follows:

a. At transformer T1, unsolder jumpers across taps 1 and 3, and 2 and 5.

b. Solder jumper across taps 2 and 3.

c. At the internal terminal strip located on the front panel directly below the two lamp assemblies, cut the jumper across resistor R34. (QRE 7.5-20 units only).

d. Replace fuse F1 with a 2.5 A rated

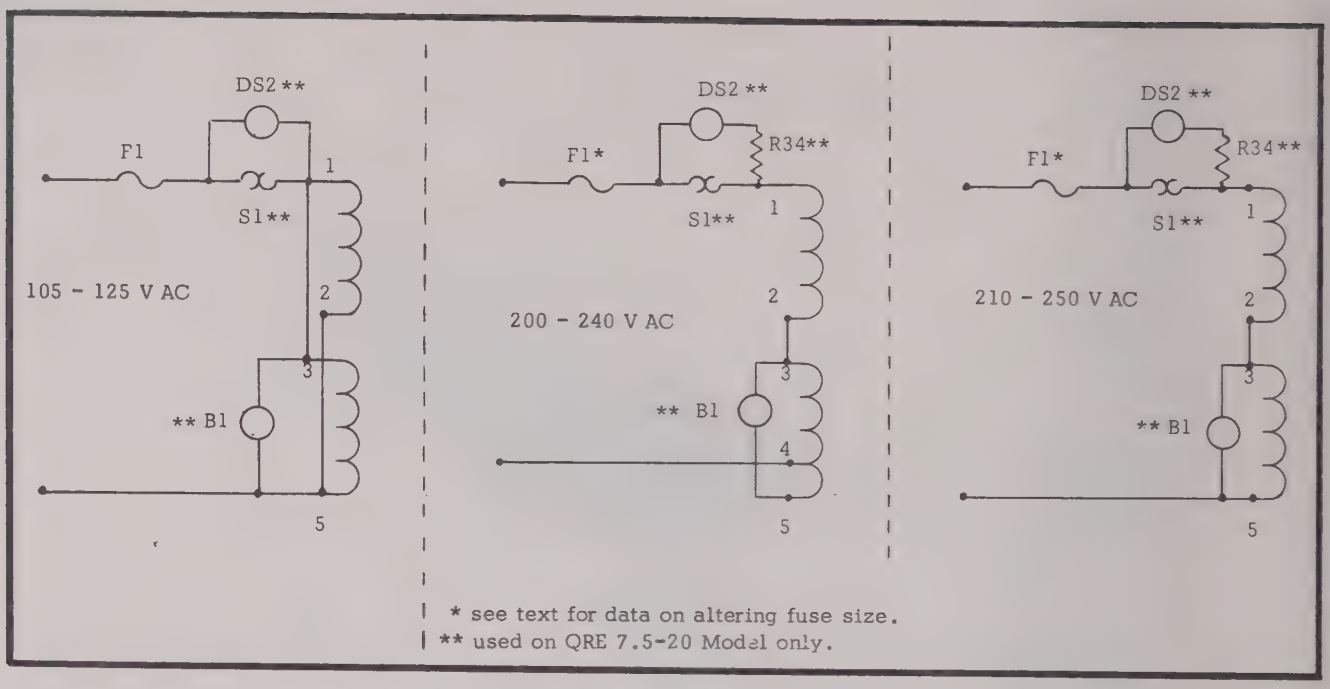


Figure 2-1. Input Connections.

fuse for the QRE 7.5-10 units. Use a 5 A fuse for the QRE 7.5-20 units.

e. Remount cover using hardware originally removed.

2-10. INPUT POWER CORD. The input power cord terminates externally in a three-prong polarized plug. The unit chassis is wired to the plug through the line cord, and therefore, the insertion of the plug into a compatible receptacle, hooked up to a grounded input, will automatically ground the unit. If a grounded input is not available, use an adapter, making sure that the adapter's external lead is well grounded.

2-11. ELECTRICAL INSPECTION.

2-12. To perform an initial electrical inspection, proceed as follows:

a. Insert line cord into a suitable receptacle. (Refer to para 2-10.)

b. Rotate VOLT. ADJ. controls fully counterclockwise.

c. Turn OVERVOLT TRIP ADJ. control fully clockwise.

d. Set POWER circuit breaker to ON.

e. Rotate VOLT.ADJ. controls fully clockwise. Unit voltmeter should indicate at least 7.5 volts.

f. Slowly turn OVERVOLT TRIP ADJ. control counterclockwise. Unit circuit breaker will open when overvoltage trip point drops below output voltage.

2-13. MECHANICAL INSTALLATION.

2-14. The unit is shipped ready for bench use. However, it may be adapted for rack mounting by simply removing the four unit feet. The rack-mounting holes are located at the front-panel ends.

SECTION III

OPERATING INSTRUCTIONS

3-1. GENERAL.

3-2. In this section, a list of the controls and indicators (Table 3-1 and Figure 3-1), along with functional descriptions, precedes the unit operating instructions. The instructions outline procedures for adapting the unit to its more common applications, including remote sensing, parallel and series operation, and resistance programming. Before putting unit into operation, some factors which determine the minimum settings of the overvoltage trip point and the current limit value should be considered (para 3-3).

3-3. PREOPERATION CONSIDERATIONS.

3-4. MINIMUM OVERVOLTAGE TRIP POINT. The minimum setting to which the overvoltage trip point should be adjusted is determined by the instantaneous output-voltage overshoot caused by a full-load to no-load change, by the overvoltage-circuit sensitivity to a full-range line variation, by the difference between the ambient at which trip point is set and the ambient at which unit is operated, and finally by the load-lead drop, if remote sensing is used. All of these are discussed in the following paragraphs. The last paragraph in the group gives a practical example of the effects of all factors.

3-5. Load and Line Changes. The unit's transient response time for a step change, full load-to-no load, is 50 μs. Within this period, there is an output voltage overshoot (E_{os}) which will cause nuisance circuit-breaker tripping if the overvoltage set point is set below the peak amplitude of the overshoot. This amplitude is a function of the unit's output inductance (Lo) and the rate of load change (di/dt). The relationship is given by $E_{os} = -L_o (di/dt)$. (It should be noted that, in general, the value of L is lower than the 0.32 μh listed in Table 1-1. For instance, at 100 kHz the output inductance is only 0.135μh (QRE 7.5-20 Model)). In addition, the sensitivity of the overvoltage-circuit trip point to line variations must be considered. This sensitivity results in a trip-point change of ± 0.1 volts about a nominal 115 V input.

3-6. Temperature Coefficient. The over-voltage-circuit temperature coefficient is ± 0.007 V/°C. This should be considered if ambient operating temperature is other than that in which trip point is set.

3-7. Remote Sensing. In remote sensing, the unit output voltage is the sum of the IR drops in the load leads plus the voltage across the load. Therefore, before setting the over-voltage trip point, the load-lead drops must first be calculated and then added to the desired load voltage. When the rear-panel output terminals are used, the internal wires from the rear to front terminals form part of the load leads. The drops in these wires must also be calculated and summed with the other drops. The QRE 7.5-10 Model internal load wires have a resistance of 0.0094 ohms; the lead resistance in a QRE 7.5-20 Model is 0.010 ohms. The sum obtained, added to the voltages determined in the preceding paragraphs, gives the minimum overvoltage setting.

3-8. Example. This paragraph provides an illustrative example of the cumulative effects of the various factors considered in para 3-5 through 3-7. First, assume the load changes at the rate of 1A/μs and input inductance is 0.135 μh; then apply the equation for determining the voltage overshoots. The overshoot amplitude is 0.135 volts. Next, assume that the line varies from 115 to 105 Vac. This would lower the trip point by 0.1 volts. For the temperature-coefficient factor, assume an ambient temperature rise of 10°C. This may lower the trip point by 0.07 volts. Finally, consider the case of remote sensing, and as an example, suppose that the application requires that 4.5 volts be supplied across a 5 A load, using 10 ft of No. 18 solid copper wire for each load lead. Unit is a QRE 7.5-10 Model. Multiplying 20 (for the two leads) by the ohms/ft. for No. 18 solid copper wire gives the lead resistance. Multiplying this product by the load current (5 A) determines the total lead voltage drop of 0.684 volts. (Note that while all other factors are a function of the power supply, the load-lead voltage drop may be altered simply by changing the wire size.) Now, the summation of the voltage from all factors is 0.989 V. For this parti-

CONTROL/INDICATOR	FUNCTION
THERMAL OVERLOAD Indicator (QRE 7.5-20 Model only)	An amber lamp which, when glowing, indicates a unit shutdown due to overheating.
POWER ON Indicator	A red lamp which, when glowing, indicates input power is applied to the primary of transformer T1.
Unit Voltmeter	A 0-10 V d-c meter connected across the SENSE terminals. Registers output voltage at output terminals in local-sensing mode, and voltage across load in remote sensing configuration.
Unit Ammeter	Connected in the positive output leg. Indicates output current.
POWER Circuit Breaker	A single-pole, 1 A-coil, 250 Vac breaker used to apply input power to, and disconnect it from, the load. The trip coil is connected in the over-voltage circuit and, when energized, opens the breaker.
OVERVOLT TRIP ADJ.	A 1000-ohm potentiometer used to adjust the overvoltage circuit trip-point.
CUR.LIMIT ADJ.	A 100-ohm potentiometer used to adjust the reference voltage for the current-limiting circuit and, consequently, the current-limit set point.
VOLT. ADJ.	A dual potentiometer which provides both fine and coarse output-voltage control. The fine control's range is 100 mV, while the coarse control's range is from 0 - 7.5 volts.

Table 3-1. Controls and Indicators.

cular application then, using 4.5 volts as the load voltage, the overvoltage trip point must be set to a minimum of 5.489 V to avoid nuisance tripping of the unit circuit breaker.

3-9. OVERVOLTAGE SET PROCEDURE. There are two procedures for setting the over-voltage trip point; one covers trip-point settings between 3.5 and 7.5 volts and the other covers settings above 7.5 volts. The first procedure is dealt with in para 3-10, and the latter is discussed in para 3-11.

3-10. Proceed as follows if the overvoltage trip point is to be set between 3.5 and 7.5 volts:

a. Rotate the VOLT.ADJ. controls fully counterclockwise.

b. Rotate OVERVOLT TRIP ADJ. control fully clockwise.

c. Insert power cord plug into a suitable receptacle (para 2-10).

d. Set POWER breaker to ON position.

e. Rotate VOLT.ADJ.control until unit voltmeter indicates the value of the desired trip-

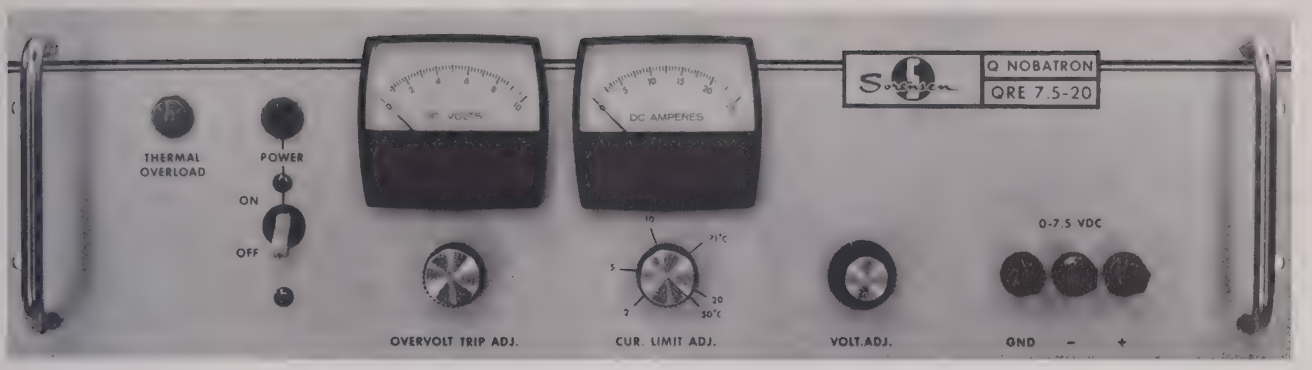


Figure 3-1. Typical QRE 7.5-V Unit (Model QRE 7.5-20 shown)

point voltage. (Refer to para 3-4 for a discussion of the minimum overvoltage set point.)

f. Turn OVERVOLT TRIP ADJ. control until the POWER breaker opens. Overvoltage trip point is now set. Any further rotation of OVERVOLT TRIP ADJ. control will alter set point.

3-11. If desired overvoltage trip point is above 7.5 volts, proceed as follows to set trip point:

a. Rotate the VOLT.ADJ. controls fully counterclockwise.

b. Turn the OVERVOLT TRIP ADJ. control fully clockwise.

c. Insert power cord plug into a compatible receptacle (para 2-10).

d. Remove link between terminal 3 and 4 on rear-mounted terminal board. Connect a 470-ohm, 1/2-watt resistor across terminals 3 and 4.

e. If trip point is between 10 and 10.5 volts, connect a 0-15 Vdc meter across output terminals.

f. Set POWER breaker to ON.

g. Turn VOLT ADJ. control until voltmeter indicates desired trip voltage. (Refer to para 3-4 for minimum overvoltage trip determination.)

h. Rotate OVERVOLT TRIP ADJ. control until POWER breaker trips. The trip point is now set. Any rotation of the trip control will change the trip-point setting.

i. Disconnect resistor and reconnect link between terminals 3 and 4.

3-12. CURRENT-LIMIT SET POINT. The crossover characteristic from voltage-regulating to current-limit operation is represented by a sharp "knee", and therefore, the current-limit setting need not be compensated for this effect. However, the current-limit set point is affected by changes in ambient temperature. This is due to the current-limit-circuit temperature coefficient, which is typically about $\pm$ 0.2%/°C. It may be compensated for by setting the trip point X % higher than the desired limit value, where X is ΔT (0.2). As an illustration, suppose that the ambient temperature changes from 25° to 35°C. ΔT, in this case, is 10. Multiplying by 0.2 gives 2 as the value of X. Therefore, for this example, the trip point should be set 2% higher than that desired. Another factor to be considered pertains to the unit-derating characteristics. Figure 1-1 shows that the rated current output decreases with ambient temperatures in the 50 to 71°C range. Now if a current-limit set point is selected which is not compatible with the rated output, little protection will be given. As an example, if limit setting on a QRE 7.5-20 Model is 20 and the unit is operated in a 71°C ambient, there will be a 7-A difference between the maximum rated output and the limit setting.

3-13. REMOTE-SENSING RECALIBRATION. If the unit is used in the remote-sensing configuration, the current-limit setting will shift downward slightly, depending upon the voltage drop in the positive load lead. This, in effect, means that the actual limit setting will be somewhat lower than the desired, if it is not compensated for. This decrease is about 5% of the current-limit setting for every 0.5 V of positive (+) load-lead drop. For example, with a limit setting of 5-A and a load-lead drop of 0.5 volts, the current-limit setting will decrease from 5 to about 4.75 A. If this effect is undersirable, it may be compensated for (1) by using the CUR.LIMIT ADJ. control to raise the limit to a new value given by:

$$I_s = I_{ld} \ (1 + Vrs/10)$$

where I_s = setting on CUR.LIMIT ADJ.control

I_{ld} = desired current-limit value

V_{rs} = voltage drop in the positive load lead

or (2) by recalibrating the current-limit circuit. The recalibration procedure follows:

a. Remove unit cover.

b. Connect the load leads to be used for supplying load at the output terminals.

c. Remove link between terminals 5 and 6, and connect a sensing lead at terminal 5.

d. Connect load leads to a 0-25 A ammeter (0.5% tolerance).

e. Connect sensing lead to meter positive terminal.

f. On component board, rotate potentiometer R37 fully counterclockwise.

g. Set CUR.LIMIT ADJ. control to "50 °C" position.

h. Rotate VOLT.ADJ. control a few degrees from the full counterclockwise position.

i. Set POWER breaker to ON.

j. Adjust potentiometer R37 until test ammeter indicates 10.5 A (QRE 7.5-10) or 21 A (QRE 7.5-20).

k. Set POWER breaker to OFF. Remove load and sensing leads from unit terminals. Reinstall link between terminals 5 and 6. Apply a locking compound to potentiometer R37, and remount cover.

3-14. LOCAL-SENSING OPERATION.

3-15. The unit is shipped ready for use in the local-sensing configuration, i.e., regulating point is at the output terminals. If the voltage drops in the load leads are expected to be prohibitive, use remote sensing (para 3-17).

3-16. To put unit into operation, proceed as follows:

a. Set OVERVOLT TRIP ADJ. control to desired trip-setting point (para 3-4).

b. Set CUR.LIMIT ADJ. control to desired current-limit value (refer to para 3-12).

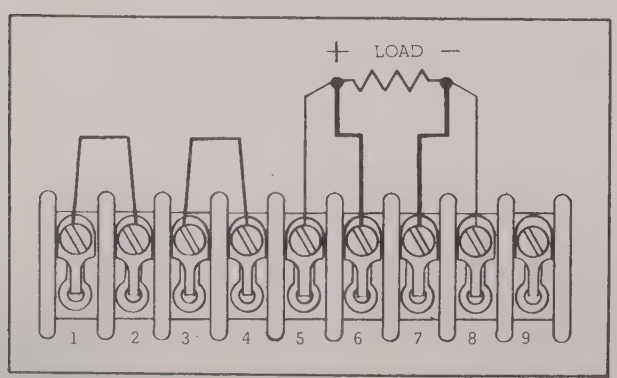


Figure 3-2. Remote Sensing

c. Rotate VOLT.ADJ. controls fully counterclockwise.

d. Set POWER breaker to ON position. POWER indicator glows.

e. Rotate coarse VOLT.ADJ. control until unit voltmeter indicates desired output voltage.

f. Set POWER breaker to OFF position.

g. Observing polarity, connect load leads from unit to load.

h. Set POWER breaker to ON position. Unit supplies precise, regulated power to load.

Note

If unit circuit breaker trips during operation, it is an indication that an overvoltage condition has occurred. To return unit to line, set breaker to ON position. If breaker continues to trip after repetitive resetting, refer to the Troubleshooting Data in Table 5-1.

3-17. REMOTE SENSING.

3-18. If variations in the load-lead voltage drops are high compared with desired regulation at load, it may be desirable to use remote sensing. With remote sensing, the unit's regulating point is extended from the output terminals to the load. To adapt the unit for remote-sensing operation, recalibrate the current-limit circuit (para 3-13), follow steps "a" through "g" of para 3-16, and before setting POWER breaker to ON, remove links between terminals 5 and 6, and 7 and 8. Then connect a sensing lead from terminal 5 to the positive side of load; next, run a sensing lead from terminal 8 to negative side of load (see Figure 3-2). Use coaxial cable or a twisted pair of wires for sensing leads, and make certain leads are firmly connected at terminations. Current in the sensing leads is 10 mA. In remote-sensing operation, transient response will degenerate slightly. If the unit's response is a critical factor, disconnect C7 and reconnect it, or an identical capacitor, across the load. Unit will then meet its transient-response specifications.

3-19. PARALLEL OPERATION.

3-20. Loads which draw currents higher than a single unit's rated output may be serviced by paralleling units. Readily accessible terminals at the unit rear facilitate the paralleling proced-

ure. QRE parallel operation is based on the "master-slave" concept, i.e., the amplifier of the "master" unit supplies drive current to all "slave" units. ("Slave" unit amplifiers are disconnected during the paralleling procedure).

3-21. The number of units which may be paralleled using the "master-slave" approach depends upon the amount of current available to drive the "slave" unit passing stages. This current is a variable from unit to unit, depending upon dissimilarities, within acceptable tolerances, in component characteristics. It has been found that some units, when used as the "master," will permit the paralleling of fifteen units. This is the optimum maximum. On the other hand, other units will permit the paralleling of only four units. This represents the worst-case maximum.

3-22. The following outlines the procedures for paralleling two units. However, the procedure need only be extended to parallel up to the maximum number of units. Derate each unit to 90% of the maximum nominal output current. Maximum system output is the sum of the derated currents.

a. Apply input power to "master" unit, set POWER breaker to ON, and use VOLT. ADJ. control to bring output voltage to desired level.

b. Set POWER breaker of "master"unit to OFF.

c. Disconnect link between terminals 1 and 2, "slave" unit. (See Figure 3-3 for a representation of parallel operation hook-up.)

d. If remote sensing is to be used, recalibrate current-limit current of "master" unit (para 3-13). Remove links between terminals 5 and 6, and 7 and 8 on "master" unit.

e. Connect a load lead from each unit positive output terminal to positive side of load. Run other load leads from the negative output terminals to negative side of load.

f. If remote sensing is desired, connect a sensing lead from terminal 5 "master" unit, to load positive; run another sensing lead from terminal 8, "master" unit, to load negative. Use coaxial cable, or a pair of twisted wires, for sensing leads.

g. Connect a lead from terminal 1, "slave" unit, to terminal 1, "master" unit.

h. Turn the OVERVOLT TRIP ADJ. control on both units to desired trip setting (refer to para 3-9).

i. Set the CUR.LIMIT ADJ. control of "master" unit to desired limit value.

j. Set POWER breaker of both units to ON. Both unit POWER indicators glow, and units

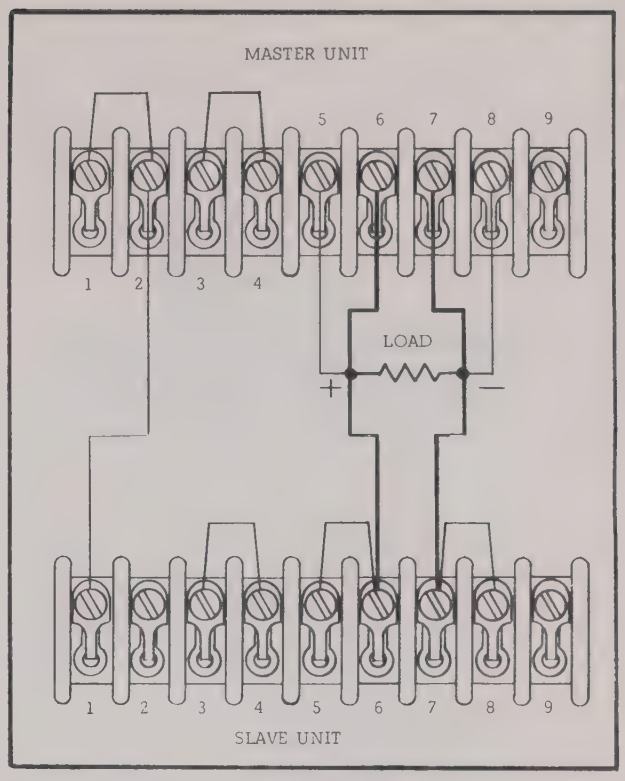


Figure 3-3. Parallel Operation (with remote sensing)

supply regulated power to load.

Note

Regulation degeneration in "master-slave" parallel operation is negligible.

3-23. SERIES OPERATION.

3-24. Series operation may be used to obtain output voltages higher than the maximum output of any one unit. The maximum output rating of a series-connected system is 200 volts. Regulation in series operation is the sum of the specified regulation for each unit. The maximum output current of a series-connected system is limited to the maximum current output of the lowest rated supply.

3-25. The following outlines the procedure for connecting two QRE's in series (see Figure 3-4). The procedure need only be extended to series connect as many units as desired within the limitations given in para 3-24.

a. At no load, apply nominal input power, set POWER breakers on both units to ON, and adjust the output voltages so that their sum

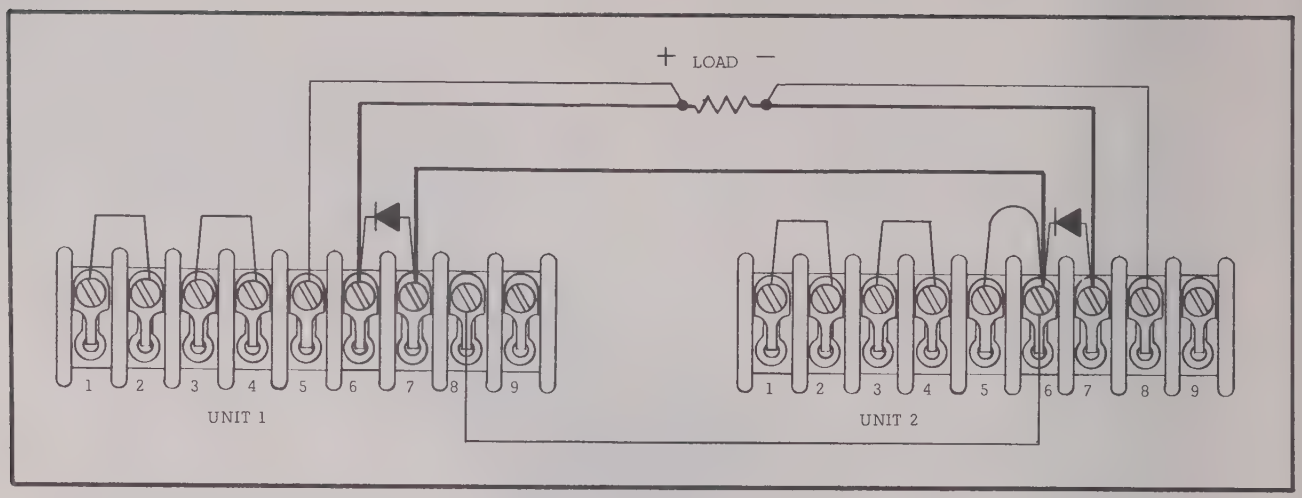


Figure 3-4. Series Operation

is equal to the desired system output voltage, plus the load-lead voltage drops. Set each unit's OVERVOLT TRIP ADJ. to the desired value.

b. Set both POWER breakers to OFF.

c. Recalibrate unit 1 current-limit circuit per para 3-13.

d. Remove links between terminals 5 and 6, and 7 and 8 on both units.

e. Connect load lead from negative output terminal, unit 1, to positive output terminal, unit 2.

f. Run a load lead from the positive output terminal of unit 1 to the positive side of load. Connect a load lead from the negative output terminal of unit 2 to the negative side of load.

g. Connect a sensing lead from terminal 8, unit 1, to terminal 6, unit 2; connect another sensing lead from terminal 5, unit 2, to terminal 6, unit 2.

h. Run a sensing lead from terminal 5, unit 1, to positive side of load. Connect a sensing lead from terminal 8, unit 2, to negative side of load.

CAUTION

To protect units' output capacitors, connect a rectifier across individual unit output terminals. Refer to para 3-26 for rectifier recommendations. Disconnect diode CR13, located internally across the SENSE terminals (5 and 8).

i. Rotate each unit's CUR.LIMIT ADJ. control to the desired limiting value.

j. Set unit POWER breakers to ON. POWER indicators glow, and system supplies regulated voltage to load.

3-26. RECTIFIER RECOMMENDATIONS. The rectifiers recommended for use in series operation should be mounted on 1/8-in. thick, flat aluminum plate, 2-1/4 x 2-1/4 in. for QRE 7.5-10 Models and 4 x 4 in. for QRE 7.5-20 Models. Two rectifiers may be mounted on a single plate, if they are of opposite polarity, i.e., one reverse and one forward. The rectifiers for QRE 7.5-10 Models may be purchased from Motorola Semiconductor Products. The Motorola number for forward-polarity devices is MR 1120 (Sorensen part no. 26-1046-1) and, for the reverse-polarity types, is MR 1120R (Sorensen p/n 26-1046-11). Mounting torque is 12-16 lb-in. For the QRE 7.5-20 Models, use a Westinghouse 302A (JEDEC No. 1N1183) for the forward types and a 335 A (JEDEC No. 1N1183R) for reverse types. Mounting torque is 20-30 lb-in.

CAUTION

Do not use insulating washers between heatsink and device.

3-27. REMOTE PROGRAMMING.

3-28. RESISTANCE. The procedure in which a calculated resistance is introduced into the sensing network in order to obtain a predetermined output is called remote programming. Its use is advantageous in those applications where unit output must be controlled from remote locations.

3-29. The programming sensitivity is 100 ± 0.5 ohms/volt. This means that, for each volt of output desired, 100 ohms must be connected into the programming circuit. In selecting a program-

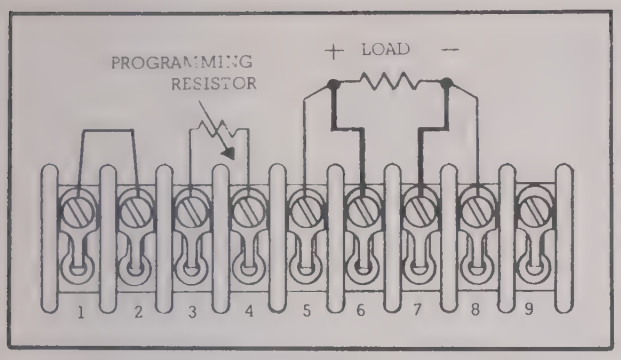


Figure 3-5. Remote Programming

ming resistor, choose one with a low temperature coefficient (± 20 ppm/°C) and a wattage rating at least ten times that calculated. The programming current is 10 mA.

3-30. To adapt unit to remote programming, see Figure 3-5 and proceed as follows:

a. Set POWER circuit breaker to OFF.

b. Turn VOLT.ADJ.controls fully counterclockwise.

c. Remove link between terminals 3 and 4, and connect programming resistor (previously calculated) across terminals. Do not use alligator clips or related types of connecting devices for programming-resistor leads. Turn down terminal screws until a good, firm connection is made. Use twisted or shielded wire for programming leads.

d. Set POWER breaker to ON and check output on unit voltmeter. Meter should indicate programmed voltage.

e. Set POWER breaker to OFF.

f. Connect load to output terminals, observing polarity.

g. Rotate OVERVOLT TRIP ADJ. control to desired trip value.

h. Set CUR.LIMIT ADJ. control to desired limit value.

i. Set POWER breaker to ON. Unit voltmeter indicates the programmed output.

Note

Rotating either VOLT.ADJ. knob will increase output voltage. If this is an undesirable feature, bypass the VOLT.ADJ. controls by first removing the link between terminals 3 and 4, and then connecting the programming resistor between terminal 3 and terminal 7.

3-31. VOLTAGE. The procedure (para 3-30) for adapting the unit for resistance programming may be applied to voltage programming, with this exception: instead of connecting the programming resistor across terminals 3 and 4, connect the voltage source. Select an ungrounded source capable of producing a low-noise, low-ripple output and of absorbing the 10 mA programming current. There is no amplification in voltage-programming operation, i.e., the unit output voltage is equal to the signal voltage. Do not use a signal greater than 7.5 volts.

SECTION IV
PRINCIPLES OF OPERATION

4-1. GENERAL.

4-2. This section outlines the circuit operation for the QRE 7.5-10 & 7.5-20 Models. The section, if used with the data provided in Section V, Maintenance, will aid in the rapid, logical isolation of unit faults. Schematic locations of the reference designations used throughout will be found in Section V.

4-3. PASSING-STAGE PRINCIPLE.

4-4. The QRE utilizes the series-passing stage principle in regulating unit output. With this approach, a variable impedance absorbs the difference between the desired regulated output and the filtered "brute-force" dc. The variable impedance is provided by a transistor stage which is fed an output-related control signal. Passing-stage operation is idealized in Figure 4-1.

4-5. BLOCK-DIAGRAM DISCUSSION.

4-6. The following discusses, in a general manner, the internal operation of a QRE. A more detailed treatment of the various sections is presented in subsequent paragraphs. Refer to Figure 4-2: the a-c input is stepped-down by the input transformer and applied across a full-wave center-tapped bridge rectifier. Output from the rectifier is filtered and fed through the passing stage to the load. This passing stage is, of course, the regulating device, absorbing the difference between the rectifier and desired output voltages. The feedback loop includes a sensing circuit which samples unit output voltage. This sample voltage is compared with a fixed reference voltage generated by the reference power supply. Resulting error signals are differentially amplified and fed to the passing stages through a series of driver amplifiers. The signals then vary the impedance of the passing stages as a function of output voltage.

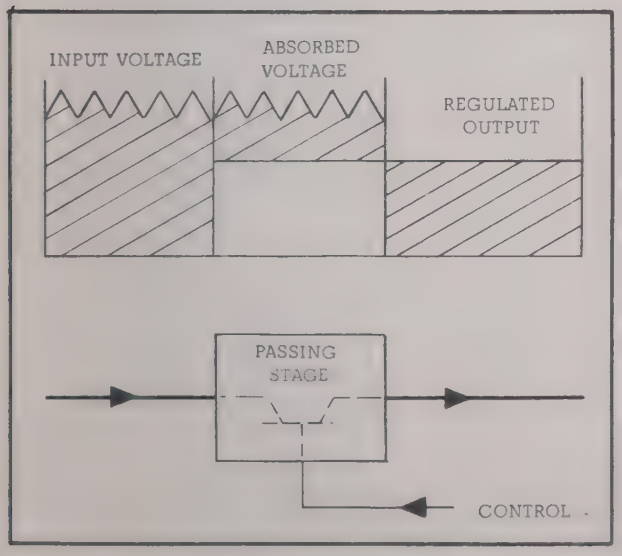


Figure 4-1. Passing Stage Principle

4-7. The overvoltage section senses the output voltage and operates to trip the unit circuit breaker when an undesirable voltage condition occurs. In the event of an overcurrent condition, the current-limit section reduces the drive on the passing stages by lowering the operating currents in the second stage of the error amplifier.

4-8. INPUT POWER SECTION.

4-9. The input power section includes main transformer T1, a full-wave, center-tapped bridge rectifier (CR1 and CR4) and output filter (C3). Capacitor (C25) is a high-frequency bypass, while capacitors (C1 and C2) suppress noise generated by rectifier commutation. A thermostat (S1), cooling fan (B1), thermal overload light (DS2) and current-limiting resistor (R34) form part of the T1 primary section in the QRE 7.5-20 unit. Pilot light (DS1), connected across a 115-volt primary of T1, indicates the presence of input power at T1.

4-10. REFERENCE POWER SUPPLY.

4-11. A constant reference voltage, used both in the sensing and error amplification section and in the current-limit section, is provided by a supply consisting of potentiometer (R15), double differential amplifier (Q6, Q7 and Q8, Q9), transistor (Q5) and a zener reference diode (CR8). Input to the reference supply is derived

from a full-wave, center-tapped bridge (CR6 and CR7) connected across a secondary of transformer (T1). Capacitor (C6) provides input filtering, and capacitors (C10 and C8) are used for stabilization.

4-12. The circuit functions as follows: a portion of the output is sampled across part of potentiometer R15, i.e., schematically, that part across the base-emitter of Q9 and resistor R16. This sample is compared with the reference voltage developed by diode CR8. Comparison error signals are differentially amplified and then fed to the base of transistor (Q5).

4-13. For an example of circuit operation, assume that the reference supply output voltage tends to rise. The voltage across R15 begins to increase and the base of Q9 becomes more positive with respect to the base of Q9 (note that the base-emitter voltage of Q8 is held constant by CR8). The operating current through Q9 increases, and as a result, the drive on Q6 decreases. The base of Q6 therefore becomes less positive with respect to the base of Q7. The operating current of Q6, which is the drive on transistor (Q5), drops and the impedance of Q5 increases. Consequently, the voltage drop across Q5 reduces the output to a regulated 9 V.

4-14. SENSING AND ERROR AMPLIFICATION.

4-15. Output sensing and error amplification are provided by the sensing string (R18A, 18B and R25) and double-differential amplifier (Q12, Q13 and Q10, Q11). Transistor (Q17), resistors (R24 and R39) and diodes (CR17 and 18) form a constant-current generator which maintains the sum of the operating currents through Q12 and Q13 at a fixed value.

4-16. The sensing string controls the potential at the base of Q12. This voltage is compared with the constant reference voltage supplied by the reference supply (para 4-10). Error signals which develop are amplified by differential amplifiers (Q12, Q13 and Q10, Q11). Amplifier output is fed to driver Q1, and subsequently, to the base of the passing stage (Q2). Q2 reacts by varying its IR drop to regulate the output to the value determined by the setting of R18A and B.

4-17. To illustrate circuit operation, assume the output voltage begins to drop. The base of Q12 will then become more positive with respect to the base of Q13. Current through Q12 will increase, and Q13's operating current decreases. As a result, the base of Q10 becomes more negative with respect to the base of Q11. The operating current through Q10, which is the amplifier output, increases. Consequently, the drive on the passing stage (Q2) increases, and Q2's impedance drops. Output voltage then increases to that value determined by the sensing resistors (R18A and B).

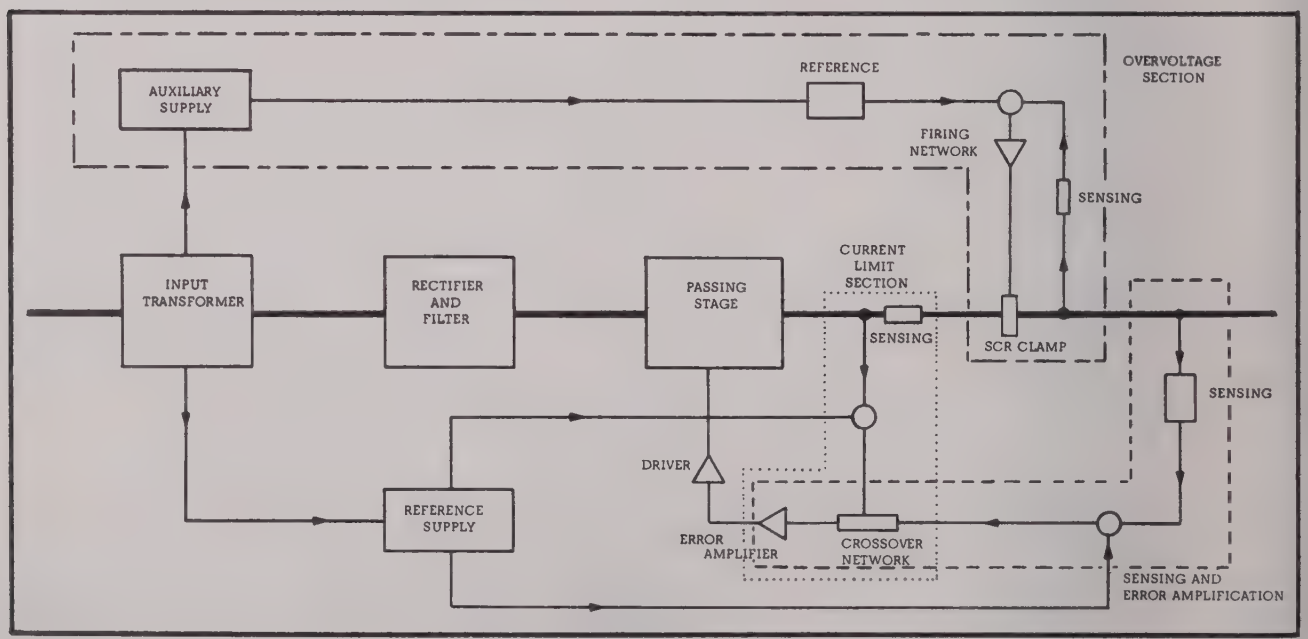


Figure 4-2. Block Diagram

4-18. DRIVERS AND PASSING STAGE.

4-19. The drivers Q1, Q14 (and Q3 in the 20 A unit) amplify the error signals from differential amplifier (Q10, Q11). These amplified signals are fed to the bases of the passing-stage transistors Q2. (Note that the passing stage in the 10 A unit has four paralleled transistors and in the 20 A unit there are six. Resistors R7 balance the voltages absorbed by each transistor).

4-20. To illustrate the operation of the drivers and passing stage, the discussion of para 4-15 is continued. As may be recalled, a dropping output voltage results in an increase in drive on the base of Q1. Q1's conduction level will rise, and its operating current and therefore the drive on the base of Q14, will increase. Q14's operating current will then rise, and the drive on the passing stage will be greater. (Note that the 20 A unit has an additional driver (Q3) between Q14 and the passing stage). As a result, the passing stage goes into a state of higher conductance (lower impedance). The absorbed voltage across the stage decreases thereby raising the output voltage. This completes the feedback loop.

4-21. CURRENT-LIMIT SECTION.

4-22. The current-limit section is comprised of differential amplifier (Q15, Q16), crossover transistor (Q4), reference string (R5, R37 and R6), resistors (R4, R8, R36, R38, and R41), and zener diode (CR5). The circuit, when functioning to limit output current, reduces the operating current of differential amplifier (Q10, Q11) and thereby increases the impedance of the passing stage. Resistor (R40) and capacitor (C23) comprise the stabilization circuit.

4-23. To illustrate circuit operation, assume that an overcurrent condition (short circuit, etc) occurs. The high load current increases the drop across sensing resistor (R41) and therefore the base of Q15 becomes more positive with respect to the base of Q16. (Note that a portion of the constant voltage output of the reference supply is applied to the base of Q16). The operating current through Q15 increases, and Q16's current decreases. (The relatively large value of R36 serves to maintain the sum of Q15's and Q16's operating currents almost constant). As Q16's operating current decreases, the voltage drop developed across R38 decreases. This voltage, under normal conditions, is sufficient to maintain Q4 in saturation. However, now as it decreases, Q4 comes out of saturation and approaches cut-off. Q10's operating current, which is the amplifier output to the driver and passing stages, is lowered, and Q2 develops a high impedance. The unit now holds the current constant while the output voltage varies inversely with the voltage drop across R41.

4-24. OVERVOLTAGE SECTION.

4-25. To protect voltage-sensitive loads, a fast-acting safety circuit, consisting basically of a differential amplifier (Q19, Q20), firing-circuit network (Q18 and R33), silicon-controlled rectifier (CR11), has been connected across the output. A separate supply, made up of a secondary of T1, rectifiers (CR19 and CR20) and filter capacitor (C27), powers the reference diode and the differential amplifier.

4-26. As an example of circuit operation, assume that the output voltage begins to rise above the trip-setting. In this condition, the base of Q20 becomes more positive with respect to the base of Q19. (Note that a constant voltage derived from CR15 is across the base-emitter of Q19). The current through Q20 increases, thus increasing the voltage drop across R31. The increasing voltage across R31 drives the firing circuit amplifier (Q18) into a state of high conduction. Q18's operating current increases, and therefore the voltage drop across R33 increases. When R33's voltage reaches or surpasses the SCR gate-cathode firing voltage, CR11 conducts. CR11 and diode CR16 then clamp the output to about 3 volts. Within 10 ms, the circuit breaker trips through the action of energized coil CB1. Capacitor C20 suppresses radio-frequency interference, preventing possible CR11 misfires.

SECTION V
MAINTENANCE

5-1. GENERAL.

5-2. This section provides troubleshooting data, periodic servicing, and calibration and performance-testing procedures. The troubleshooting data should be used in conjunction with both the schematic diagram (Figure 5-2) which gives voltage check points, and Section IV, which outlines the principles of operation. In addition, Figure 5-1, 5-3 and 5-4 physically locate the parts appearing on the schematic. Any questions pertaining to repair should be directed to the nearest Sorensen representative (a list is included with the unit) or to the Service Dept., Raytheon Co., Sorensen Operation, Richards Avenue, Norwalk, Connecticut 06856. Include the model and serial numbers in any correspondence. Should it be necessary to return a unit to the factory for repair, authorization from the Sorensen Service Dept. must be obtained first. Raytheon Company will not assume responsibility for units returned without prior authorization.

5-3. PERIODIC SERVICING.

5-4. No periodic servicing is required for the QRE 7.5-10 Model; periodic servicing of the QRE 7.5-20 Model entails only the lubrication of the cooling fan. The intervals at which the fan is to be oiled are a function of both the unit's duty cycle and the ambient temperature. If the unit is operated continuously in high ambients, the fan should be lubricated every six months. If, on the other hand, the unit is operated intermittently at room temperature (20 to 25°C) or below, lubrication need only take place at 12-month periods. For operating conditions between the two duty and temperature extremes, select an interval between 6 and 12 months. The lubricant recommended by Rotron Manufacturing Company, Woodstock, N.Y., is supplied in kit form and may be purchased under Rotron part number 19263.

5-5. In addition to lubricating the fan, it is recommended that, whenever a unit is taken off the line, it be cleaned. Use naptha, or an equivalent solvent, on painted surfaces. Wash front panel with a weak solution of soap and warm water. Use compressed air at a pressure of 5 psi to blow dust from in and around parts.

5-6. TROUBLESHOOTING.

5-7. Table 5-1 provides a list of malfunction symptoms along with a tabulation of the possible cause or causes for each symptom. Note that the failure of one component may result in a "chain reaction" effect. For example, if one or more of the passing stages (Q2) opens, the remainder of the Q2's may become overloaded and subsequently fail. In a like manner, if a diode in one of the four, full-wave rectifiers fails, its complementary rectifier and the main transformer may be damaged.

5-8. CALIBRATION.

5-9. Following the replacement of any differential-amplifier components, recalibration is recommended. Differential amplifiers are used in the reference supply, current-limiting section, overvoltage section, and sensing and error-amplification section. If any of the internal adjustment potentiometers (R15, R27, R37) are replaced, recalibration is required.

5-10. To calibrate the QRE 7.5-10 or 7.5-20, proceed as follows:

a. Remove unit cover.

b. Rotate VOLT.ADJ. control fully counterclockwise.

c. Turn OVERVOLT TRIP ADJ. and CUR. LIMIT ADJ. controls fully clockwise.

d. Adjustment of potentiometer (R27) is not the same for both Models.

(1) In the QRE 7.5-10 Model, the overvoltage board, to which potentiometer R27 is attached, is stacked at rear, right-hand side of unit below the main component board. Access to R27 is through the grill at unit base. Insert screwdriver

SYMPTOM	PROBABLE CAUSE
No output; fuse not blown	a. No input. b. POWER breaker in OFF position. c. See "No output, overvoltage circuit operative."
No output; overvoltage circuit operative[1]	a. In reference supply, transistor Q9, Q7, diode CR8 or potentiometer R15 wiper open. Transistors Q8, Q6, or Q5 shorted. b. In error amplifier, transistor Q13 or Q11 open. Shorted Q10 or Q12. c. In drivers and passing stage, Q1, Q14, Q3 or Q2[2] shorted. d. Silicon controlled rectifier CR11[3] shorted.
No output; fuse blown	a. Fan B1 shorted (QRE 7.5-20 Model only). b. One of T1's secondary diodes shorted[4].
No output; THERMAL OVERLOAD indicator glows (QRE 7.5-20 Model only)	a. Fan B1 open. b. Unit operated in high ambient environment.
No output or low voltage; unit ammeter indicates current equal to CUR.LIMIT ADJ. control setting	a. Unit overloaded or shorted externally. b. Diode CR13 shorted.
Unit voltmeter indicates negative output	a. Transistor Q1, Q3[2], Q4, Q10, Q12, Q14,[2] Q16, or Q17 open. b. Transistor Q11 or Q13 shorted.
Unit voltmeter indicates low output	a. In reference supply, transistor Q9 or Q7 or diode CR8 shorted. Transistor Q8, Q6 or Q5 open. b. Q13 shorted.

(1) If the POWER circuit breaker trips during operation, it is an indication that the overvoltage circuit is operative.

(2) When replacing any of the Q2's, Q3 or Q14, apply a few drops of silicone oil (Silicone Fluid, 200, Dow Corning Co., Midland, Michigan, or an equivalent) to transistor mounting surfaces. Hardware mounting torque is 8 lb-in.

(3) If a replacement rectifier is to be installed, reuse hardware originally removed. Mounting torque is 25 lb-in. Apply silicone oil (Silicone Fluid 200, Dow Corning Co., Midland, Michigan, or an equivalent) to both sides of mica insulator.

(4) If either CR1 or CR4 is to be replaced, coat mounting surfaces with a thin film of silicone oil. (see note 2). Rectifier nut torque is 13-14 lb-in.

Table 5-1. Troubleshooting Data

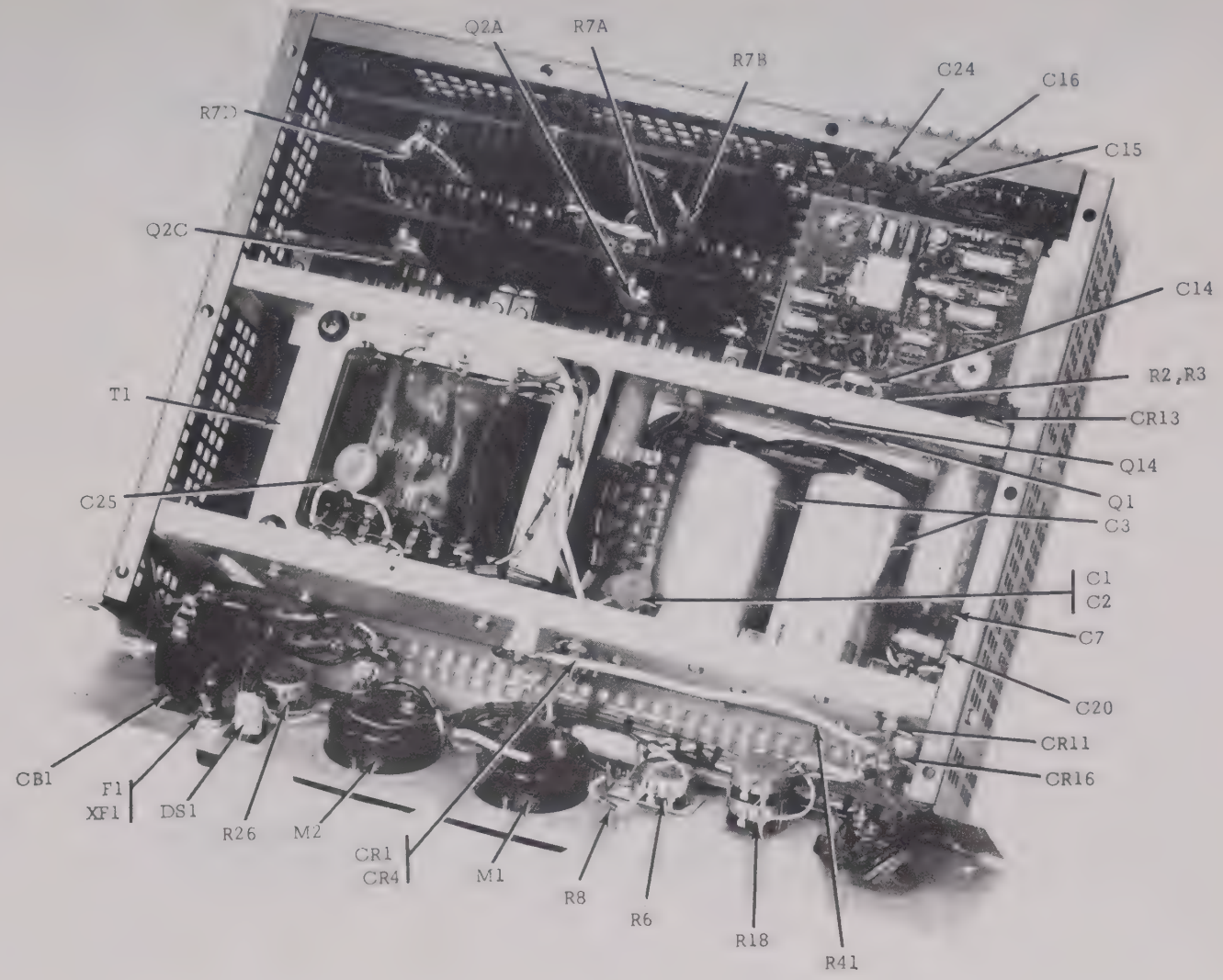


Figure 5-1A. Partial Disassembly, QRE 7.5-10 Model

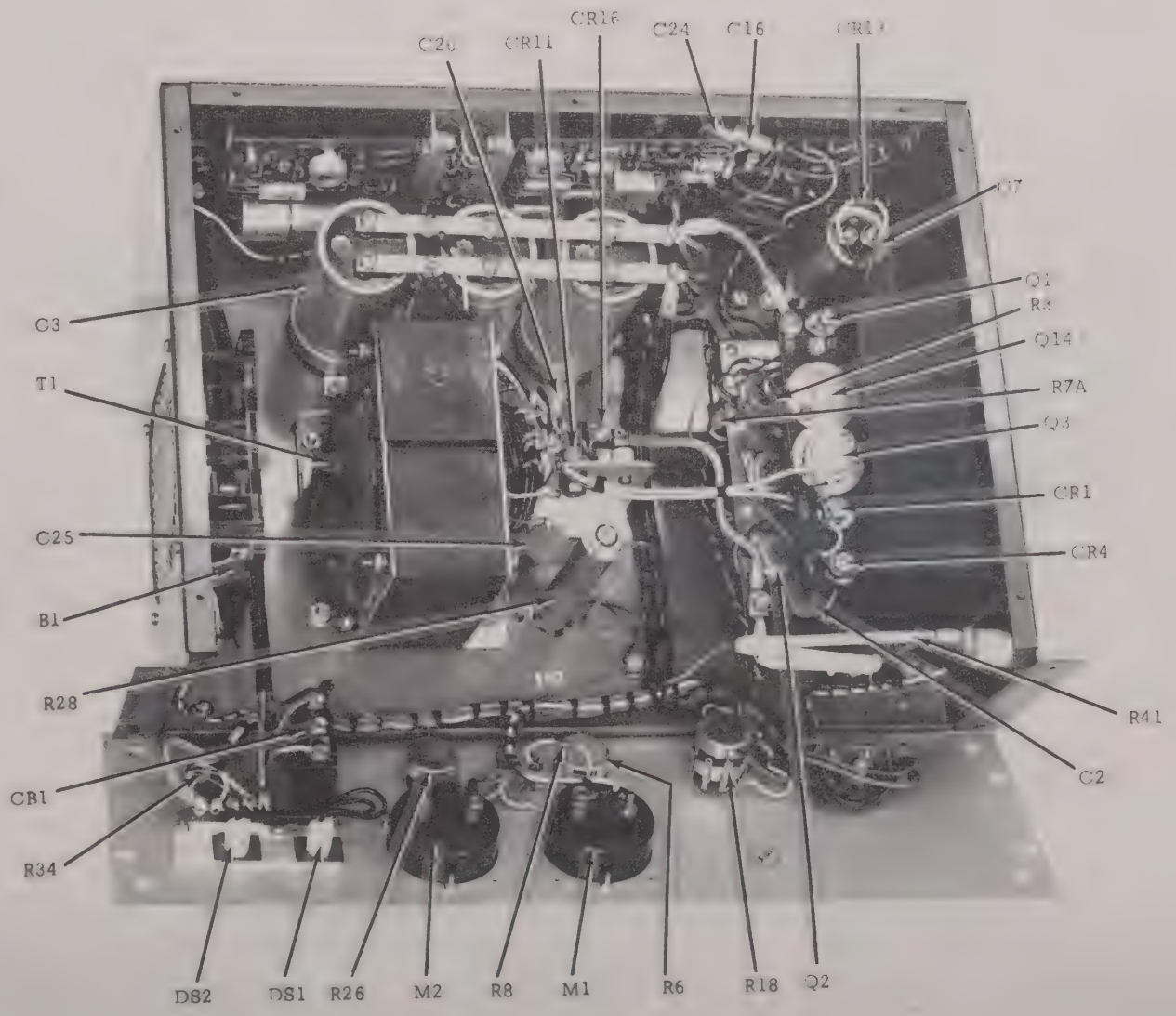
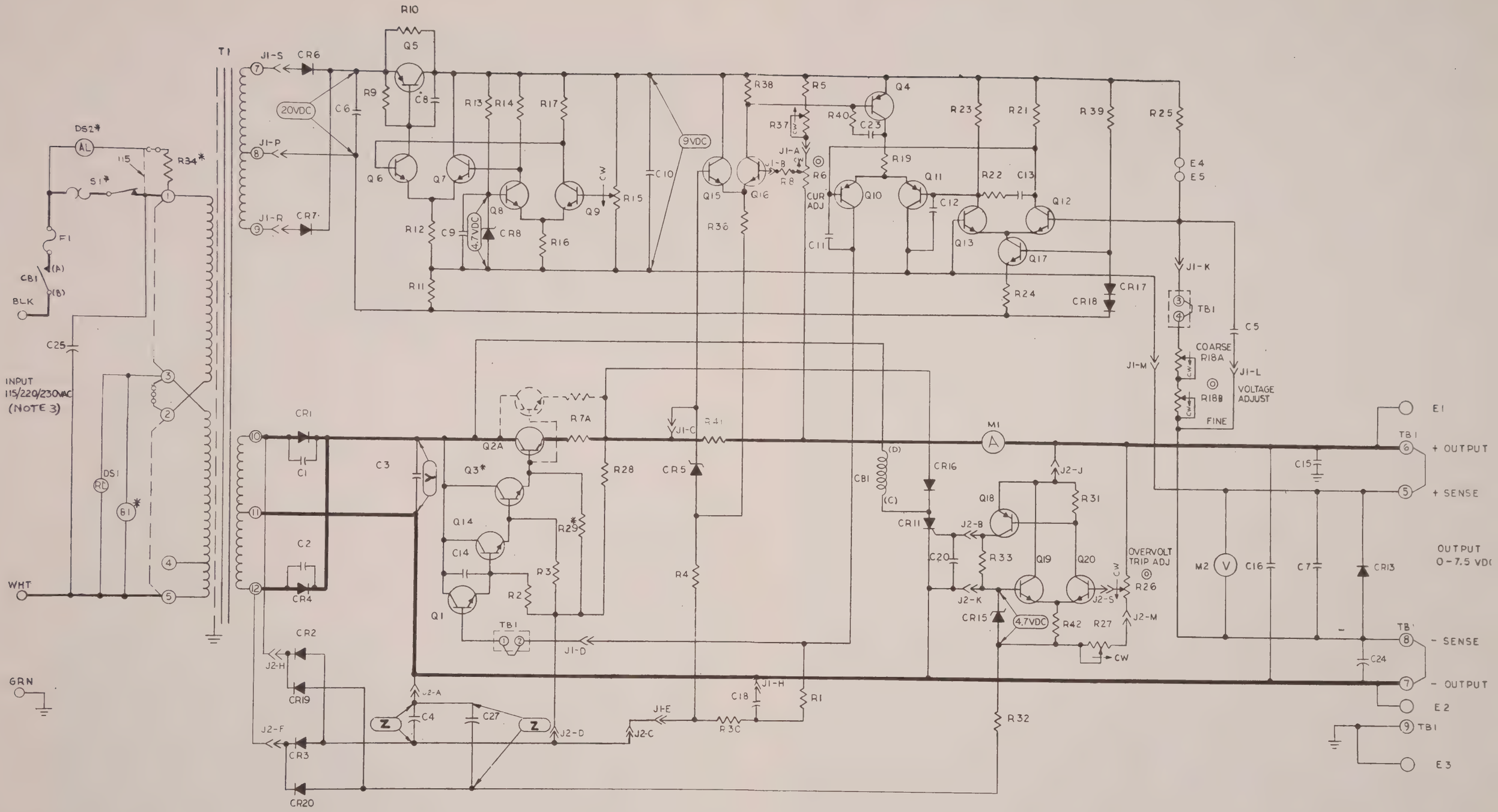


Figure 5-1B. Partial Disassembly, QRE 7.5-20 Model



VOLTAGE CHART (VDC)

QRE	7.5-10	7.5-20
Y	15	16
Z	16	17

* USED ON QRE 7.5-20 MODEL ONLY

NOTES

1 ©DENOTES PANEL CONTROL
2 ALL VOLTAGES MEASURED AT NOMINAL INPUT, NOMINAL OUTPUT, NO LOAD
3 SEE FIGURE 2-1 FOR INPUT CONNECTION DETAIL

FIGURE 5-4. SCHEMATIC DIAGRAM.

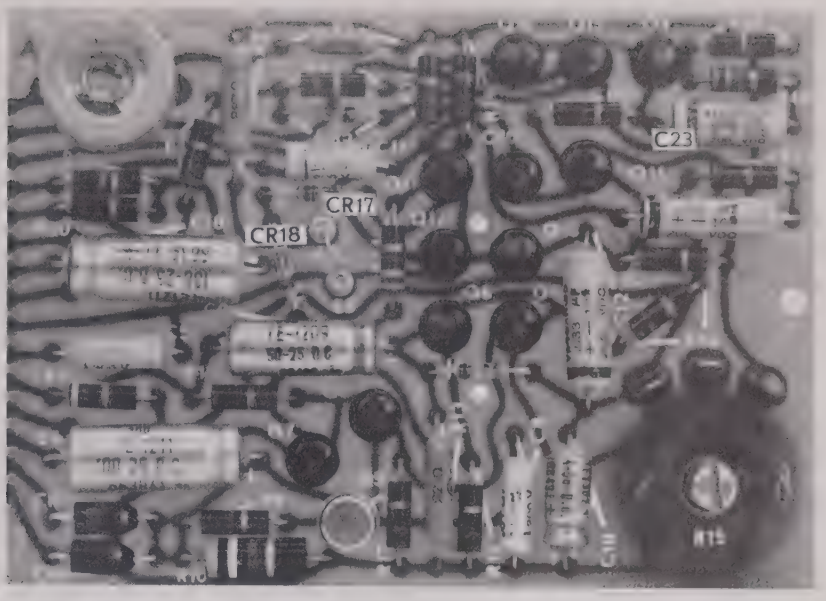


Figure 5-4. Error Amplifier and Current-Limit Component Board (thermal cover removed)

through grill and rotate potentiometer fully counterclockwise.

(2) In the QRE 7.5-20 Model, the overvoltage board is adjacent to the main component board and parallel to the rear panel. Turn R27, located on board, fully clockwise.

e. Set potentiometer (R15), located on component board, to center of rotation range.

f. Rotate potentiometer (R37), located on component board, fully clockwise.

g. Remove link between terminals 3 and 4 on rear-mounted external terminal board (TB1). Connect a precision-resistor box across terminals. Set box resistance to 750 ohms.

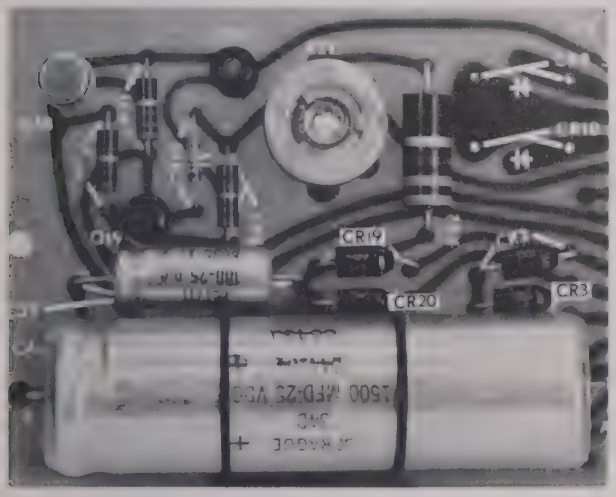


Figure 5-3. Overvoltage Component Board

h. Connect a sensitive d-c voltmeter across the output terminals.

i. Insert power-cord plug into a suitable receptacle at which a nominal 115 Vac, 60 Hz is available. Set POWER breaker to ON position.

j. Adjust potentiometer (R15) to obtain an output of 7.5 ± .03 V.

k. Rotate VOLT.ADJ. control to obtain a 10.5 volt output. Then, turn potentiometer (R27) until POWER circuit breaker trips.

l. Rotate VOLT.ADJ. control fully counterclockwise, and then set POWER breaker to ON.

m. Turn VOLT.ADJ. control slowly clockwise while observing voltmeter. Breaker should open at an output between 10.4 and 10.6 volts.

n. Disconnect voltmeter and resistance box, and reinsert link between terminals 3 and 4.

o. Set POWER breaker to ON. At no load and nominal input, rotate VOLT.ADJ. control from stop-to-stop. At left-hand stop, unit voltmeter should indicate 0, and at right-hand stop, indication should be at least 7.5 volts.

p. Using VOLT.ADJ. control obtain an output of 7.5 volts. Set CUR. LIMIT ADJ. control to "50°C" position.

q. Set POWER breaker to OFF and connect a suitable ammeter across the output terminals. Rotate potentiometer (R37) fully counterclockwise.

r. Set POWER breaker to ON. Rotate potentiometer (R37) until test ammeter indicates 10.5 A (QRE 7.5-10 Model) or 21 A (QRE 7.5-20

Model). Set POWER breaker to OFF and disconnect test ammeter.

s. Apply locking compound to potentiometers R15, R27 and R37, and remount cover.

5-11. PERFORMANCE TESTING.

5-12. OUTPUT RIPPLE. To measure unit output ripple, proceed as follows:

a. Connect a test set-up as shown in Figure 5-5. Set oscilloscope for 0.5 mV vertical and 10 ms/cm horizontal. (Oscilloscope should have at least a 30 MHz bandwidth). Select a 150 V range for a-c voltmeter. Choose a 0.5 mV range for RMS meter and 25 A range for d-c ammeter. The variac should be capable of supplying 105 to 125 V ac at 3 A (QRE 7.5-10 Model) or 6 A (QRE 7.5-20 Model). Use a resistive load with a current drawing capacity of at least 11 A (QRE 7.5-10 Model) or 22 A (QRE 7.5-20 Model). Use differential voltmeter as a TVM (or VTVM). Select a 15-volt range.

b. Apply a 115 Vac input.

c. Turn CUR.LIMIT ADJ. control to "50°C" position.

d. Rotate OVERVOLT TRIP ADJ. control fully clockwise.

e. Set POWER breaker to ON.

f. At no load, adjust unit output to 7.5 volts.

g. Observe oscilloscope and RMS voltmeter. Voltmeter should indicate no more than 0.30 mV; oscilloscope should display a peak-to-peak voltage no greater than 2 mV.

h. Set POWER breaker to OFF.

i. If a regulation test is to be performed, disconnect oscilloscope and RMS voltmeter, and refer to para 5-13. Otherwise, disconnect entire test hook-up.

5-13. REGULATION. To determine unit's output regulation, proceed as follows:

a. Connect unit to test set-up shown in Figure 5-5. The oscilloscope and RMS voltmeter are not necessary. Convert the differential voltmeter to act as a precision potentiometer. Select an internal voltage equal to 7.5 volts, and set the null sensitivity to the 10 mV range.

b. Apply a 115 Vac, 60 Hz input.

c. Set POWER breaker to ON.

d. At no load, adjust unit output to obtain a null indication on voltmeter.

e. With a-c voltmeter indicating 115 Vac, increase load on unit until d-c ammeter reads 10 A (QRE 7.5-10) or 20 A (QRE 7.5-20). Record deviation from voltmeter null position.

f. Adjust voltmeter internal voltage to regain the null position. Then, with full load on unit, vary input voltage at 60 Hz from 105 to 125 Vac. Note the deviation.

g. Sum the deviations recorded in steps e, and f. The total should be less than 1.5 mV.

h. Set POWER breaker to OFF. Disconnect test set-up.

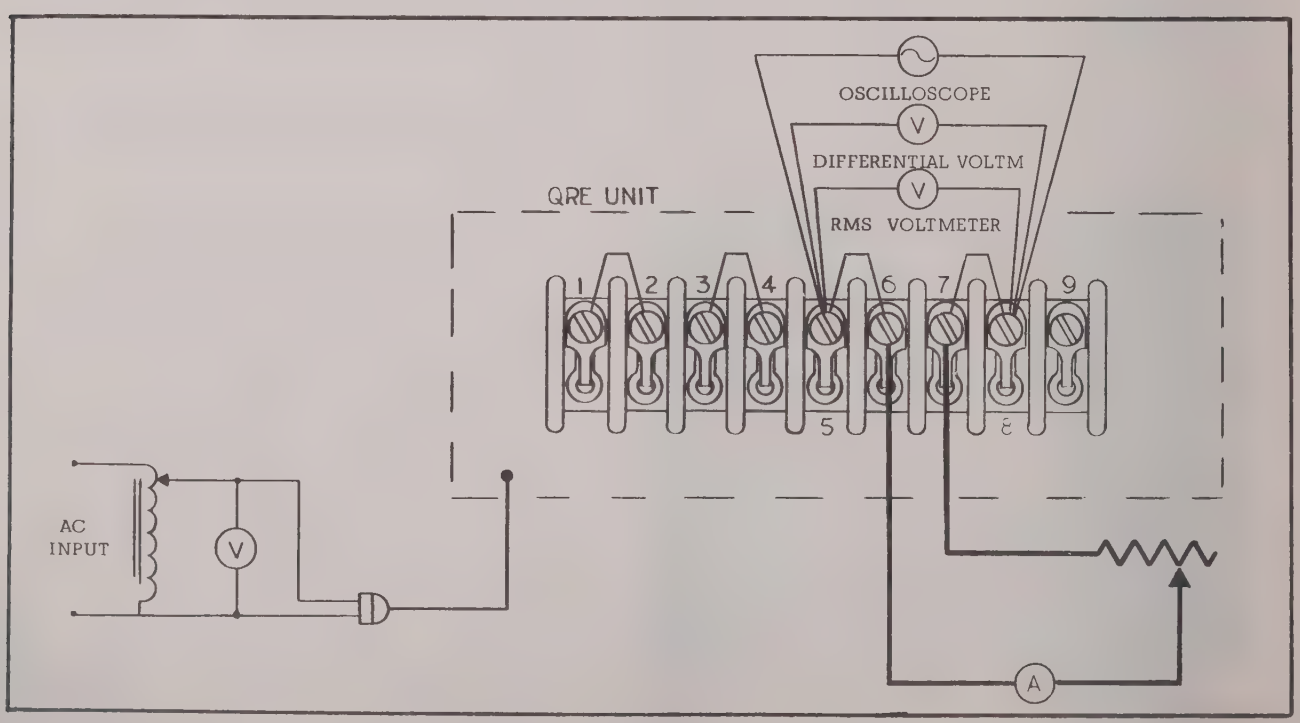


Figure 5-5. Performance Test Set-up.

SECTION VI
REPLACEMENT PARTS LIST

6-1. GENERAL.

6-2. This section provides a replacement parts list for the QRE 7.5-10 and 7.5-20 Models. The list is keyed to both the parts-locating photographs (Figure 5-1, 5-3, and 5-4) and the schematic diagram (Figure 5-2).

6-3. MANUFACTURER CODING.

6-4. The column headed MFR.CODE contains a listing of letter designators which, when applied to the tabulation that follows, will give the manufacturer from whom a particular item may be purchased. If no manufacturer's part number is listed in the MANUFACTURER PART NO. column, the part may be ordered from the indicated manufacturer by using the Sorensen part number and a complete description of the item.

AB	Allen Bradley Company
AX	Aerovox Corp.
BM	Bussman Manufacturing Div.McGraw Co.
BR	Bourns, Inc.
CB	Centralab, Div. of Globe Union,Inc.
CS	Clarostat Manufacturing Co.Inc.
CTS	CTS Corp.
FC	Fairchild Semiconductor
GE	General Electric Co.
HM	Heinemann Electric Co.
ID	Industrial Devices, Inc.
IRC	International Resistance Co.
LF	Littelfuse Co.
MA	Motorola Semiconductor Products
RCA	Radio Corporation of America
RDM	Radio Material Co.,Div.P.R.Mallory
RN	Rotron Mfg. Co.
RT	Raytheon Company
SP	Sprague Electric Company
SR	Sorensen Operation, Raytheon Company
ST	Solitron Devices, Incorporated
TI	Texas Instrument
WL	Ward Leonard Electric Co.

6-5. ORDERING PARTS.

6-6. When ordering parts from Raytheon Co., Sorensen Operation, include manufacturer's part number, the Sorensen part number and the unit model number. Address orders to:

Raytheon Company
Sorensen Operation
Richards Avenue
Norwalk, Connecticut 06856

REF. DES	DESCRIPTION	SORENSEN PART NO.	MANUFACTURER PART NO.	MANUFACTURER CODE
B 1	Fan	91-1000-2	Muffin	RN*
CB 1	Circuit Breaker	92-352	JA1-A-6-1-250P	HM
C 1,2	Capacitor, 0.05 µF, 500 Vdc	24-2010		CB
C 3	Capacitor, 15 mF, 20 Vdc	24-2459-2		SP
C 4	Capacitor, 1 mF, 25 Vdc	24-2452-4		SP≠
	Capacitor, 1.5 mF, 25 Vdc	24-2452-3		SP*
C 5,8	Capacitor, 0.01 µF, 200 Vdc	24-2409-7		AX
C 6,18,27	Capacitor, 100 µF, 25 Vdc	24-2279-14		AX
C 7	Capacitor, 6.4 mF, 15 Vdc	24-2454-4		SP≠
	Capacitor, 10 mF, 7.5 Vdc	24-2469-1		SP*
C 9	Capacitor, 50 µF, 25 Vdc	24-2279-12		SP
C 10	Capacitor, 4 µF, 50 Vdc	24-2280-4		SP
C 11,14	Capacitor, 0.0068 µF, 200 Vdc	24-2409-6		AX
C 12,13	Capacitor, 0.033 µF, 200 Vdc	24-2409-10		AX
C 15	Capacitor, 0.015 µF, 200 Vdc	24-2409-8		AX
C 16	Capacitor, 100 µF, 15 Vdc	24-2278-15		SP
C 20	Capacitor, 0.1 µF, 200 Vdc	24-2409-13		AX
C 23,24	Capacitor, 0.022 µF, 200 Vdc	24-2409-9		AX
C 25	Capacitor, 0.02 µF, 900 Vac	24-026		RDM
CR 1,4	Rectifier	26-1046-1	MR 1120	MA
CR 2,3	Rectifier	26-1027-4	HC 68	ST≠
	Rectifier	26-1002-4	2A100	ST*
CR 5,8,15	Rectifier	26-211	1N750A	MA
CR 6,7,19,20	Rectifier	26-158-1	CER 68	ST
CR 11	Rectifier	26-178-1	C30UX7	GE
CR 13	Rectifier	26-158-1	CER 68	ST≠
	Rectifier	26-1002-3	2A50	ST*
CR 16	Rectifier	26-1006-1	MR 1030A	MA
CR 17,18	Rectifier	26-1017	RD 9119	RT
DS 1	Pilot light assembly (red)	43-308	1050A1	ID
DS 2	Pilot light assembly (amber)	43-321		ID*
F 1	Fuse, 5 A, 250 V, 3 AG	42-413	312005	LF≠
	Fuse, 10 A, 250 V, 3 AB	42-1809	ABC-10	BM*
M 1	Ammeter, 0 - 15 A	94-433-10		SR≠
	Ammeter, 0 - 25 A	94-433-21		SR*
M 2	Voltmeter, 0 - 10 V	94-549-1		SR
Q 1	Transistor	18-145	RT 9343	RT
Q 2	Transistor	18-151	2N3055	RCA
Q 3	Transistor	18-151	2N3055	RCA*
Q 4,10,11	Transistor	18-143	2N3638	FC
Q 5,18	Transistor	18-146	RT 9338	RT
Q 6,7,8,9,12, 13,15,16,17, 19,20	Transistor	18-144	FSC 3641	FC
Q 14	Transistor	18-142	40312	RCA

≠ Used on QRE 7.5-10 only
* Used on QRE 7.5-20 only

Table 6-1. Replacement Parts List (Sheet 1 of 2)

REF. DES.	DESCRIPTION	SORENSEN PART NO	MANUFACTURER	
			PART NO.	CODE
R 1	Resistor, 10k ohm, 1/2 W	27-133	EB 1031	AB
R 2	Resistor, 3.3k ohm, 1/2 W	27-140	EB 3321	AB
R 3	Resistor, 560 ohm, 2 W	27-1164	HB 5611	AB≠
	Resistor, 1800 ohm, 1/2 W	27-176	EB 1821	AB*
R 4,31	Resistor, 680 ohm, 1/2 W	27-156	EB 6811	AB
R 5	Resistor, 2k ohm, 1/4 W	28-1225		IRC
R 6	Potentiometer, 100 ohm, 2 W	29-499		CS
R 7	Resistor, 0.39 ohm, 7 W	27-1522		WL≠
	Resistor, 0.33 ohm, 7 W	27-1523		WL*
R 8,9,19	Resistor, 220 ohm, 1/2 W	27-101	EB 2211	AB
R 10	Resistor, 390 ohm, 1 W	28-703	GB 3911	AB
R 11	Resistor, 47 ohm, 1/2 W	27-181	EB 4701	AB
R 12	Resistor, 820 ohm, 1/2 W	27-182	EB 8211	AB
R 13	Resistor, 221 ohm, 1/2 W	28-1188		IRC
R 14,16,17	Resistor, 1800 ohm, 1/2 W	27-176	EB 1821	AB
R 15	Potentiometer, 2000 ohm, 2 W	29-409		CS
R 18	Pot., dual 750/10 ohm, 2 W	29-501		CS
R 19	Resistor, 220 ohm, 1/2 W	27-101	EB 2211	AB
R 21,23	Resistor, 1500 ohm, 1/2 W	27-171	EB 1521	AB
R 22	Resistor, 120 ohm, 1/2 W	27-1107	EB 1211	AB
R 24,40	Resistor, 330 ohm, 1/2 W	27-102	EB 3311	AB
R 25	Resistor, 887 ohm, 1/2 W	28-1216		IRC
R 26	Potentiometer, 1000 ohm, 2 W	29-500	3067P-1-102	BR
R 27	Potentiometer, 1000 ohm, 1.5 W	29-503		CTS
R 28	Resistor, 40 ohm, 25 W	27-765	25F40	WL≠
	Resistor, 25 ohm, 50 W	27-809	50F25	WL*
R 29	Resistor, 470 ohm, 2 W	27-358	HB 4711	AB*
R 30,39	Resistor, 2200 ohm, 1/2 W	27-152	EB 2221	AB
R 32	Resistor, 330 ohm, 2 W	27-361	HB 3311	AB
R 33	Resistor, 1000 ohm, 1/2 W	27-103	EB 1021	AB
R 34	Resistor, 56k ohm, 1/2 W	27-161	EB 5631	AB*
R 36	Resistor, 2.7k ohm, 1/2 W	27-174	EB 2721	AB
R 37	Resistor, 2.5k ohm, 2 W	29-504		CTS
R 38	Resistor, 1.2k ohm, 1/2 W	27-1110	EB 1221	AB
R 41	Resistor, 25m ohm,	190-3703		SR
	Resistor, 12.5m ohm, 5 W	190-3730		SR
R 42	Resistor, 1000 ohm,1/2 W	27-103	EB 1021	AB
S 1	Thermostat	92-517	20700L	TI*
T 1	Transformer	126-2693		SR≠
	Transformer	126-2692		SR*
XF 1	Holder, Fuse	42-459	342012	LF

≠ Used on QRE 7.5-10 only
* Used on QRE 7.5-20 only

Table 6-1. Replacement Parts List (Sheet 2 of 2)

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